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Spillover analysis across FinTech, ESG, and renewable energy indices before and during the Russia–Ukraine war: International evidence

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Abstract

This study is epicentral to analyze the impact of the Russia–Ukraine war on the financial markets, specifically focusing on the connectedness and spillover dynamics of FinTech, Environmental, Social, and Governance (ESG), renewable energy, gold, and Morgan Stanley Capital International (MSCI) indices in developed and emerging countries. Data are collected from Thomson Reuters, ranging from May 8, 2020, to May 11, 2022, and a time-varying parameter vector autoregression (TVP-VAR) and the dynamic conditional correlation (DCC) generalized autoregressive conditional heteroskedasticity (GARCH) t-Copula (DCC-GARCH t-Copula) are used to analyze the data. The results show that FinTech, ESG, and MSCI are net transmitters in developed countries, whereas gold and renewable energy are net receivers pre- and during war periods. ESG and MSCI are net transmitters in emerging countries, while FinTech, renewable energy, and gold become net receivers in both periods. The hedging ratio sheds light on the costs and weights of efficient pair investments that might change in the context of each region and under the combined scenario. The study has important implications for merchant bankers, policymakers, investors, hedgers, and risk managers.

KEYWORDS

connectedness, ESG, FinTech, gold, MSCI, renewable energy, Russia–Ukraine war

1 | INTRODUCTION

As the world awakes from the COVID-19 pandemic and paves the way for recovery amid challenges such as the fear of new virus strains, surging inflation, new monetary policy, and central bank frameworks, the tragedy of the Russia–Ukraine war adds another black swan to the flock with far-reaching geopolitical repercussions that have roiled global markets with inflation and higher interest rates. Studies on the impact of conflict and war on stock markets have been conducted in the past, with some documenting that war events can have an impact on stock market returns. Schneider and Troeger (2006) looked at the effects of Iraq's invasion of Kuwait on markets, while Fernandez (2008) examined the impact of the United States–Iraq war on global markets. Gu et al. (2021) analyzed the implications of the Sino–United States conflict on China's stock market, and Hassan et al. (2022) examined the effects of Indian border conflicts on the National Stock Exchange Fifty (NIFTY) indices. Moreover, a number of studies have been conducted in recent years to assess the impact of the COVID-19 pandemic on the spillover effect of stock markets and asset classes (Akhtaruzzaman et al., 2021, 2022; Banerjee, 2021; Corbet et al., 2020; Kinateder et al., 2021), while other studies have also shown the negative impact of the pandemic on various industries (Batten et al., 2022).

The ongoing conflict between Russia and Ukraine, which began in February 2014, has had a significant impact on the global financial markets, with Russia's energy exports being a key point of contention. Following Russia's full-scale invasion, the Russian government is facing severe economic sanctions imposed by various countries and corporations worldwide (Funakoshi et al., 2022). The Russia–Ukraine war has had a significant impact on financial markets around the world, being one of the most major conflicts in Europe since World War II. Numerous studies have been conducted on the impact of the Russia–Ukraine war on financial markets (Boubaker et al., 2022; Boungou & Yatié, 2022; Chortane & Pandey, 2022; Pandey & Kumar, 2022; Umar et al., 2022; Yousaf et al., 2022). The global stock markets have seen negative cumulative abnormal returns with varying impacts across different countries (Boubaker et al., 2022). Boubaker et al. (2022) have identified country-specific variables that play a significant role in driving these impacts. Yousaf et al. (2022) have also found similar impacts on the stock markets of G20+ countries. Abbassi et al. (2022) and Pandey and Kumar (2022) have also provided firm-level evidence on the effects of the war on the G7 stock markets and the global tourism sector, respectively.

The war has had a particularly negative effect on the energy sector, as Russia is one of the world's top exporters of oil, gas, and coal. In March 2022, oil surged over USD 130 per barrel for the first time since 2008, and gas prices have spiked to all-time highs.[1] Financial and energy sanctions have aggravated international trade and precipitated market volatility. In a news conference on March 10, 2022, Christine Lagarde, president of the European Central Bank, stated that the "Russia–Ukraine war will have a material impact on economic activity and inflation through higher energy and commodity prices, the disruption of international commerce, and weaker confidence."[2] However, the sanctions have also increased demand for clean energy as a substitute for conventional energy, spurring growth in the renewable energy sector (Mathis & Wade, 2022). Equities with low-carbon transition opportunities performed better (Deng et al., 2022). The literature on the war's impact on markets is growing, with early studies (Abbassi et al., 2022; Boubaker et al., 2022) providing evidence of the varied effects on global stock markets.

Moreover, the recent era is marked by the symbiotic convergence of the two megatrends: Financial Technology (FinTech) and sustainable finance, which are reshaping nimble financial markets[3] (Chueca Vergara & Ferruz Agudo, 2021). The new hype of digital transformation conquers the financial services in the resource efficiencies, synergies, and price improvement of environmental risks and investment opportunities (Hinson et al., 2019). FinTech is characterized by its ability to transmit large amounts of data quickly and at a reduced cost. The analogy of financial data transmission with spillover effects is fascinating in portfolio management and behavioral investment decisions, specifically in the sustainable finance sector, where financial resources can be efficiently channeled to environmentally sustainable businesses (Sachs et al., 2019).

The study adds to the literature by investigating the impact of the war on ESG, renewable energy, and Fintech industries, while controlling for gold. Moreover, analyzing connectedness before and during this war surge is a critical scenario to understand investors' behavior and markets' spillover. Intrinsically, connectedness and spillover dynamics play a critical role in explaining systemic risk, and their typical measures gauge markets' interdependencies and interrelationships. In this sense, a higher rate of connectedness implies a proportionate level of interdependence (Balcilar et al., 2021).

Despite the many papers on spillover and connectedness, the literature lacks an investigation of the relationship between ESG, FinTech, and renewable energy markets. The literature on ESG investments has focused on the connectedness and spillover of ESG, mainly green bonds, with other financial markets, such as stock, currencies, and energy markets, to determine whether they are independent of traditional markets and offer diversification benefits (Akhtaruzzaman et al., 2021; Broadstock & Cheng, 2019; Reboredo & Ugolini, 2020; Reboredo, 2018; Reboredo et al., 2020). Ferrer et al. (2021) studied the relationship between the green bond market and conventional and energy markets in terms of time–frequency connectedness. They found a strong connection between green bonds and the treasury and corporate bond markets. However, they observed limited connectedness between green bonds and the general stock market, the renewable energy equity sector, and the crude oil market, regardless of the time horizon. Another strand of literature focused on green energy stocks and their interactions with oil prices (Dawar et al., 2021; Hanif et al., 2021; Naeem et al., 2020; Saeed et al., 2021; Xia et al., 2019) and with cryptocurrencies (Li & Meng, 2022).

However, there is a lack of research on the relationship between ESG investments, FinTech, and renewable energy in one study. Given the increased interest in ESG investments and FinTech, the analysis of these investments with renewable energy is highly crucial for investors. First, FinTech companies are becoming increasingly involved in the renewable energy sector, and their performance can be influenced by the volatility of the renewable energy markets. Second, the integration of ESG considerations into financial decision-making and the growth of the renewable energy sector are both driven by the same underlying trends, such as climate change and the shift toward a low-carbon economy. As such, it is likely that the volatility spillover between these three sectors is closely linked. Finally, understanding the volatility spillover between ESG, FinTech, and renewable energy can also be useful for policymakers, as it can help them to design policies that can better manage the risks and opportunities associated with these sectors and support the transition to a sustainable future.

Accordingly, this study aims to investigate the connectedness and spillover effects across various equity indices in developed and emerging markets. Our sample consists of the daily closing prices of five categories of indices covering FinTech, ESG, renewable energy, gold, and Morgan Stanley Capital International (MSCI), enabling us to analyze the spillover and portfolio diversification benefits across these well-known market segments in developed versus emerging countries. Motivated by the growing importance of global sustainable investing, FinTech, and renewable energy, we seek to answer the following research questions: (1) How are ESG equity markets, FinTech equity markets, and renewable energy markets in developed/emerging/combined countries interconnected? (2) How has the interconnectedness of these markets evolved during a specific historical event, such as the Russia–Ukraine war?

The paper contributes to the existing literature in various ways. First, to our knowledge, this is the first paper to examine the spillover effects between ESG equity, FinTech, and renewable energy indices. This adds to the existing literature on connectedness and provides insight into the interdependence between these markets. Second, the studies examining the connectedness and spillover between green investments and other assets mostly focus on green bonds rather than green stocks. However, this paper considers ESG and contributes to the existing literature by classifying ESG portfolios into developed and developing markets. Third, the studies considering ESG primarily focus on their connectedness with traditional stocks, and most related studies focus on the return and volatility transmission between green energy stocks and oil prices. However, this paper examines dynamic connectedness and volatility spillover between ESG, FinTech, and renewable energy, and with a different technique. Furthermore, it offers optimal portfolio weights and hedge ratios for investors. Fourth, this paper fills a gap by considering the period with the most recent downturns, represented by the Russia– Ukraine war, which allows us to examine the impact of this event on the connectedness patterns. This is particularly valuable for global investors, traders, and portfolio managers as it provides insight into whether diversification across ESG, FinTech, and renewable energy markets can be achieved during turbulent periods. Overall, our study provides important new insights into the connectedness patterns between ESG equity, FinTech, and renewable energy markets, and has important implications for investment strategy. Finally, this paper adopts recent methodological approaches, namely, time-varying parameter vector autoregression (TVP-VAR) and the dynamic conditional correlation (DCC) generalized autoregressive conditional heteroskedasticity (GARCH) t-Copula (DCC-GARCH t-Copula) to investigate the dynamic structure of connectedness over the period covering the COVID-19 outbreak.

The rest of the paper is organized as follows. Section 2 reviews the literature on connectedness, while Section 3 describes the data and methodology. Section 4 presents the connectedness results, while Section 5 discusses the hedge ratio and portfolio weights. Section 6 exposes the main findings. Finally, Section 7 concludes the study.

2 | LITERATURE REVIEW

Within the investment decision process, novel strategies account for the importance of integrating ESG, FinTech, and renewable energy companies besides traditional financial assets and commodities. This has become a valuable practice for portfolio managers and analysts, as most of them are tilting portfolios toward the assets with the highest ESG ranks. As global and regional financial networks are neither given nor static, scholars and researchers face significant challenges in discovering connectedness intensity conjectured with the dynamics of price prediction, return, and volatility. The cross-section of stock price reactions offers a particularly informative preview of the future economic impact of the Russia–Ukraine war, including the effect on the energy transition (Deng et al., 2022).

Many studies have evaluated the transmission of returns and volatility among some developed and emerging countries. Still, there is a dearth of analysis of the contagion effects between FinTech, ESG, renewable energy, gold, and MSCI in the mentioned regions. For instance, Li and Giles (2015) also analyzed the spillover between developed and emerging stock markets. Additionally, some studies concluded that important investment strategies rely on international diversification and investment in emerging markets (Goetzmann & Kumar, 2005).

The Russian invasion of Ukraine is likely to affect the global economy in three different ways: direct, through international trade; indirect, through worldwide commodity and energy market shifts; and macroeconomic, as policy implementation and business decisions may have to be deferred or adjusted to manage any fallout from the crisis.[4] Moreover, the Intergovernmental Panel on Climate Change (Bashmakov et al., 2022) report focused on the war's impact on accelerating or retarding the transition to a low-carbon economy. Chepeliev et al. (2022) argued that restricting Russia's fossil fuel exports would have considerable environmental cobenefits. Such restrictions can moderate the adverse effects on European household incomes, but can have large negative effects on the Russian economy. Ferrara et al. (2022) utilized high-frequency aggregate financial market data and inferred that the downside risks for the macroeconomy perceived by financial markets in the euro area are about three times higher than those for the US economy. Deng et al. (2022) investigated the reactions of 3500 global stocks by considering three phases: Build-up (from the time North Atlantic Treaty Organization put its troops on standby on January 24 to February 23); Outbreak (from February 24, the day of the invasion, to March 8, the day after the US announced a ban on Russian oil, gas, and coal); and Continuation (from 9 to March 31). They conclude with divergent results. While stocks with high climate transition risk did well in the United States, they did not exhibit such outperformance in Europe given its dependency on Russian oil and gas. Based on the World Bank's latest Economic Update, the Russia–Ukraine war is hitting the emerging market and developing countries in the Europe and Central Asia region, in addition to mounting concerns of a sharp global slowdown, surging inflation and debt, and a spike in poverty levels. The economic impact has reverberated through multiple channels, including commodity and financial markets, trade and migration links, and adverse effects on confidence.[5]

Boungou and Yatié (2022) studied a sample of 94 countries and found that countries that have condemned the war and those that share borders with Russia and Ukraine have been negatively impacted. Umar et al. (2022) also found that the escalation of geopolitical risk caused by the Russia–Ukraine war has had a significant effect on financial and commodity markets. Lo et al. (2022) studied the effect on the financial markets of countries dependent on Russian goods, and Chortane and Pandey (2022) investigated the impact on the value of global currencies against the US dollar. Additionally, Theiri et al. (2022) examined the impact on cryptocurrency liquidity, and Yarovaya and Mirza (2022) looked at the effect on equity funds in 40 countries. Nerlinger and Utz (2022) have shown that energy firms experienced positive cumulative average abnormal returns around the event date. Tosun and Eshraghi (2022) reported that equity markets are acutely sensitive to corporate decisions in times of political conflict. Liu et al. (2021) conducted a study to investigate the dynamic dependence and spillover effects between the green bond market and various global and sectoral clean energy markets. The results of their analysis indicate that extreme movements in the clean energy market have a systematic impact on the green bond market, indicating a strong dependence and spillover relationship between the two markets. Recognizing the common goal of improving environmental impacts shared by green bonds and clean energy stocks, Nguyen et al. (2021) investigated the interdependence between these two environmentally friendly asset types. They found a low and negative correlation between green bonds and stocks and commodities. In a separate study, Le et al. (2021) expanded their analysis to include FinTech and cryptocurrencies with green bonds. Their findings indicate that oil, gold, and green bonds are net receivers, and that shock transmissions from FinTech to these assets are lower than those to other assets.

Moreover, sustainable development and green finance have gradually become mainstream globally. Among the numerous green financial derivatives, referring to environmental, social, and corporate governance, the green stock market is developing rapidly in various economies worldwide (Friede et al., 2015). In recent years, vast amounts of money have started pouring into the ESG stock market (Koutsokostas et al., 2019). In the context of G20, ESG proved to be beneficial during COVID-19, but its effect seems to be closely tied up to its pillars, income level, and firm-specific variables (El Khoury et al., 2022). Hence, ESG investing can be seen as a shield during periods of market turmoil. Similarly, Nakai et al. (2016) found that Japanese ESG funds were better equipped than conventional funds to absorb the negative shock caused by the bankruptcy of Lehman Brothers.

In 2020, sustainable financing, including ESG funds and sustainable bonds, saw a significant increase compared to 2019. However, the negative impact of the pandemic on renewable energy projects resulting in an abrupt decline in global economic activity has impacted investor confidence. The additional investment must be in renewable energy infrastructure to ensure the continent's long-term development, requiring public and private sector engagement (Zavyalova et al., 2018). Policymakers must identify and solve environmental and investment concerns to gather the support of mainstream investors in green finance (Sharma et al., 2022). Some recent studies find no difference in the financial returns from sustainable investment avenues and their corresponding alternatives, suggesting that the investor is not required to cover any extra cost when making a sustainable investment (Sharma et al., 2021). Taghizadeh-Hesary and Yoshino (2019) studied spillover tax returns to mitigate the risk and improve the returns of green projects.

Further, Taghizadeh-Hesary et al. (2021) concluded that renewable energy power purchase agreements could be funded using tax revenue generated by the spillover impact of the green electricity supply. In a study from Italy, Magazzino et al. (2021) concluded, by employing wavelength analysis, that there is a causal flow between energy consumption and economic growth, though the causality is only significant in the short term, that is, 4 years or less. Correspondingly, Sharma et al. (2022) observed a higher association between green investments, while the green and conventional financial markets are more tangibly associated over the short term. Moreover, Naeem et al. (2021) observe a bidirectional relationship between green bonds, the USD index, and the conventional bond index.

Current debates focused explicitly on the hedging and safe-haven properties of gold and cryptocurrencies. For instance, Beckmann et al. (2015) reported on the effectiveness of gold as a hedge against the stock. Similarly, Urquhart and Zhang (2019) worked on cryptocurrencies and found them an alternative safe-haven asset class. Some studies considered cryptocurrencies and gold within the same empirical investigation (Lucey & Li, 2015) and found that cryptocurrencies are not stable over time (Klein et al., 2018). A recent study by Thampanya et al. (2020) raised concerns about the hedging ability of both gold and cryptocurrencies concerning the stock market, whereas, in a contemporary study, Huynh et al. (2020) argued that although the fourth industrial revolution has created new investment opportunities in the form of technology indices and cryptocurrencies, the significance of traditional assets such as gold has not been diminished. Given that the debates regarding hedge effectiveness and the safe-haven characteristics of various asset classes are still unsettled, the COVID-19 pandemic has given it a new context. Within that context, this study explores the spillover effect between FinTech and other financial assets during the COVID-19 crisis. For instance, Zhang et al. (2017) found a unidirectional Granger causality running between peer-to-peer and banks by using a bootstrapped panel causality analysis in China. Yao et al. (2018) found a significantly positive relationship between third-party payment and the traditional financial industries utilizing the VAR impulse response model. Li et al. (2020) found that there is a positive relationship between FinTech institutions and financial institutions by using a Granger causality test.

Hypothesis 1 – *The transmission/receiver role of ESG, FinTech, gold, and renewable energy markets is conditioned by region versus international contexts.*

Hypothesis 2 – *The pair-wise and overall total connectedness is impacted by the Russia–Ukraine war.*

3 | DATA AND METHODOLOGY

3.1 | Data

The data were collected from Thomson Reuters and ranged from May 8, 2020, to May 11, 2022. We relied on the following indices: FinTech developed index, FinTech emerging index, renewable energy developed index, renewable energy emerging index, FTSE developed ESG index, and FTSE emerging ESG index, in addition to gold developed index, gold emerging index, MSCI developed index, and MSCI emerging index. However, since the FinTech index in emerging countries was only available from September 2021, the sample period for the emerging indices ranged from September 1, 2021, to May 11, 2022 (the most recent data at the time of the analysis). The data series for all of the risk factors were converted into returns using the logarithm function. Figure 1 displays the return plot (Figure 1a for developed indices and Figure 1b for emerging indices).

3.2 | Methodology

3.2.1 | TVP-VAR

To measure the return interconnectedness among those indices, this paper adopted the TVP-VAR methodology of Antonakakis and Gabauer (2017). This methodology extends the dynamic connectedness framework of Diebold and Yilmaz (2012, 2015) by overcoming the shortcomings of the framework. Namely, TVP-VAR is not outlier-sensitive, does not require an arbitrary rolling window, and ensures no loss of observations (Antonakakis et al., 2020).

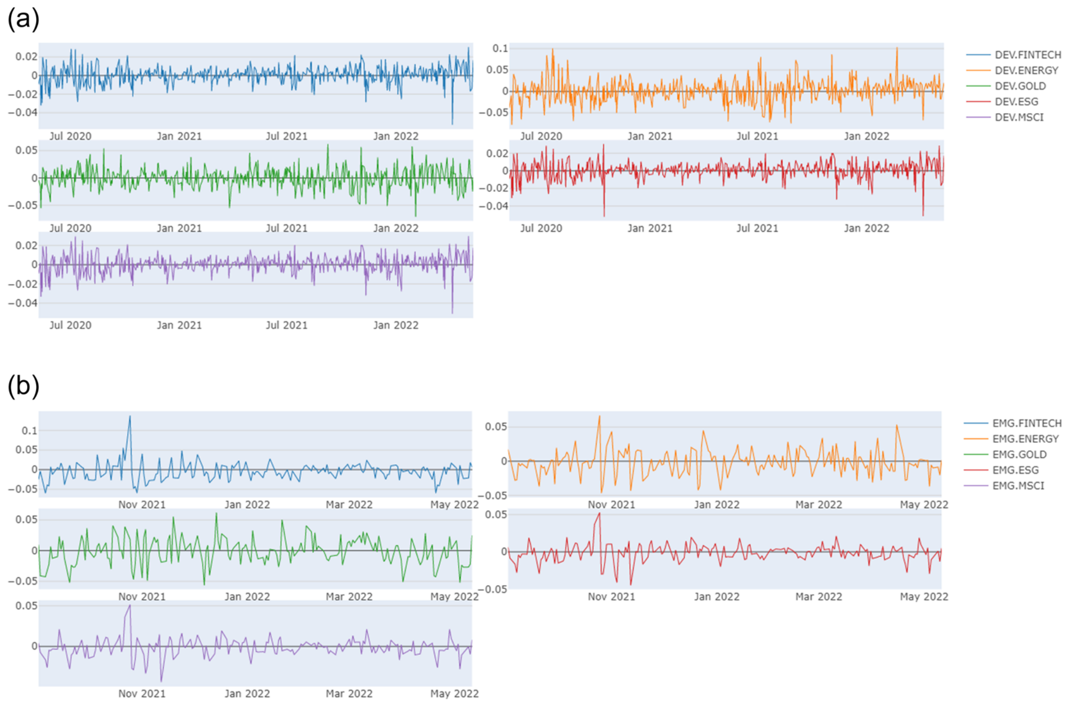


FIGURE 1 Return plots. (a) Developed indices; (b) emerging indices.

The TVP-VAR model is outlined in the following sets of equations. Let z_t be a $(N \times 1)$ dimensional vector consisting of N number of sectors. The TVP-VAR model is based on the following sets of equations:

$$Y_t = B_t Y_{t-1} + u_t; \quad u_t \sim N(0, S_t), \tag{1}$$

$$B_t = B_{t-1} + v_t; \quad v_t \sim N(0, R_t), \tag{2}$$

where B_t is a time-varying $(N \times N)$ dimensional coefficient matrix with an $N \times N$ variance–covariance matrix, Y_t and Y_{t-1} are an $N \times 1$ and $Np \times 1$ conditional vector, and u_t and v_t are two different error terms defined by the vector $(N \times 1)$ and $(N^2 \times 1)$, respectively. S_t and R_t are $(N \times N)$ and $(N^2 \times N^2)$ matrices that show the time-varying variance–covariance matrices of the error terms u_t and v_t, respectively. The connectedness index approach uses the impulse response functions of Koop et al. (1996) and the generalized forecast error-variance decompositions (GFEVD) by using the Wold representation theorem:

$$Y_t = A_t u_{t-1} + u_t. \tag{3}$$

Our focus is on the h-step error variance in the forecasting variable i that is due to shocks on variable j.

$$\tilde{\varphi}^{g}_{\mathrm{ij,t}}(h) = \frac{\sum_{t=1,}^{h-1} \tilde{\psi}^{2,g}_{ij,t}}{\sum_{i=1}^{N} \sum_{t=1,}^{h-1} \tilde{\psi}^{2,g}_{ij,t}}, \tag{4}$$

where $\tilde{\varphi}^{g}_{\mathrm{ij,t}}(h)$ denotes the h-step ahead GFEVD, $\tilde{\psi}^{g}_{ij,t}(h) = S^{-\frac{1}{2}}_{\mathrm{ij,t}} A_{h,t} \sum_t u_{ij,t}$; $\sum_{j=1,}^{N} \tilde{\varphi}^{g}_{\mathrm{ij,t}}(h) = 1$ and $\sum_{i,j=1,}^{N} \tilde{\varphi}^{N}_{\mathrm{ij,t}}(h) = N$.

Based on GFEVD, four connectedness measures are calculated. The directional spillover transmitted by variable i to all other variables j, or *connectedness TO others*, is expressed in the following equation:

$$TO_{jt} = C^{g}_{\mathrm{i \to j,t}}(h) = \frac{\sum_{j=1,\ i \neq j}^{N} \tilde{\varphi}^{g}_{ji,t}(\mathrm{h})}{\sum_{i,j=1}^{N} \tilde{\varphi}^{g}_{ji,t}(\mathrm{h})} \times 100. \tag{5}$$

The directional spillover received by variable i from other variables j, or *the total directional connectedness FROM others,* is expressed as follows:

$$FROM_{jt} = C^{g}_{\mathrm{i \leftarrow j,t}}(h) = \frac{\sum_{j=1, i \neq j}^{N} \tilde{\theta}^{g}_{ij,t}(\mathrm{h})}{\sum_{i,j=1}^{N} \tilde{\theta}^{g}_{ij,t}(\mathrm{h})} \times 100. \tag{6}$$

The *net total directional connectedness* is the difference between the connectedness transmitted *TO* and the total connectedness received *FROM* others. A positive value indicates a net transmission, while a negative value indicates a net receiver:

$$NET : TO_{jt} - FROM_{jt} : C^{g}_{\mathrm{i \to j,t}}(h) - C^{g}_{\mathrm{i \leftarrow j,t}}(h). \tag{7}$$

Finally, the total connectedness index (TCI) is calculated as

$$TCI_t := N^{-1} \sum_{j=1}^{N} TO_{jt} = N^{-1} \sum_{j=1}^{N} FROM_{jt}. \tag{8}$$

3.2.2 | DCC-GARCH-GARCH t-copula

To construct the optimal hedging and portfolio strategies, we employed the DCC GARCH t-Copula (DCC-GARCH t-Copula) model to estimate the conditional (co)variances, and DCCs. The model can be explained as follows:

$$r_t = H_t^{-1/2} z_t \; z_t \sim t_{\eta}, \tag{9}$$

where $\mathrm{H_t}$ is the time-varying variance–covariance matrix with $N \times N$ matrix of conditional covariances of r_t, z_t is the $N \times 1$ vector of the standardized residuals, and t_η is an N-dimensional multivariate normal distribution with η degrees of freedom. In this paper, the model is estimated with the copula function, which enables the modeling of dependencies across random variables. Let $F_{X_1, \ldots, X_N}$ be the joint distribution function of the random variables X_1,

..., X_N with continuous marginal distribution functions. The N-dimensional copula distribution function C (Sklar, 1973) can be written as:

$$C(u_1, ..., u_N) = F_{x_1, ..., ..., X_N} \quad (F_{x_1}^{-1}(u_1), ... (F_{X_N}^{-1}(u_N)). \tag{10}$$

Copulas based on the estimated DCC-GACRH t-copula model are based upon:

$$C(u_1, ..., u_N|R_{t,\eta}) = t_\eta \quad (F_{x_1}^{-1}(u_{1|\bullet 1}), ... (F_{X_N}^{-1}(u_{N|\bullet N})), \tag{11}$$

where $F_{x_1}^{-1}(u_{1|\bullet i})$ represents the conditional distribution and $\bullet i$ represents the estimated parameters of the selected univariate GARCH model, within the DCC-GACRH t-Copula model. For the DCCs, the DCC model of Engle (2002) is used in which the $N \times N$ matrix of conditional covariances can be written as:

$$H_t = D_t \quad R_t \quad D_t, \tag{12}$$

where D_t= diag $(h_{iit}^{0.5}, ... h_{NNt}^{0.5})$ is a diagonal matrix of the square root conditional variances and R_t is the matrix of the time-varying correlations.

$$R_t = \text{diag} \ \ (q_{ii,t}^{-0.5}, ... q_{NNt}^{-0.5})Q_t \text{diag} \ \ (q_{ii,t}^{-0.5}, ... q_{NNt}^{-0.5}), \tag{13}$$

where $Q_t = q_{ij,t}$is a $N \times N$ symmetric positive definitive matrix.

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha u_{t-1}u_{t-1}^{'} + \beta Q_{t-1}, \tag{14}$$

where u_t is the unconditional variance–covariance matrix of the standardized residuals, α is the shock parameter, and β is the persistency parameter. Finally, the GARCH model can be written as:

$$h_t = \dot{\omega} + \alpha(\varepsilon_{t-1})^2 + \beta h_{t-1}. \tag{15}$$

Dynamic hedge ratios

The hedge ratios are calculated following Kroner and Sultan (1993), while the optimal portfolio weights are based on Kroner and Ng (1998).

Hedge ratios are defined as the cost of hedging 1 USD long position in variable i with a β_{ijt} USD short position in variable j, calculated as

$$\beta_{ijt} = \frac{h_{ijt}}{h_{jjt}}, \tag{16}$$

where h_{ijt} is the conditional covariance of variables i and j. From the above equation, we can see that a higher conditional variance (denominator) leads to lower long-position hedging costs, whereas an increase in the conditional covariances (numerator) will increase the long-position hedging costs.

Dynamic portfolio weights

Finally, the dynamic portfolio weights between variables i and j are calculated based on:

$$w_{ijt} = \frac{h_{jjt} - h_{ijt}}{h_{iit} - 2h_{ijt} + h_{jjt}}, \tag{17}$$

where W_{ijt} is the weight of variable I in a USD portfolio made of two variables i and j.

To avoid the weighting of more than one or less than zero, the following restrictions are imposed on the weights to ensure that they are bounded between 0 and 1 (only long positions):

$$\begin{cases} 0 if \quad w_{ijt} < 0, \\ w_{ijt} \quad if \quad 0 \le w_{ijt} \le 1, \\ 1 if w_{ijt} > 1. \end{cases} \tag{18}$$

Hedging effectiveness (HE)

To calculate the HE of both techniques, we follow Ederington (1979), written as:

$$r_\beta = x_{it} - \beta_{ijt} x_{jt}, \tag{19}$$

$$r_w = w_{ijt} x_{it} + (1 - w_{ijt}) x_{jt}, \tag{20}$$

$$HE_i = 1 - (Var(r_{w,\beta})/(Var(r_{\text{unhedged}}). \tag{21}$$

where $(Var(r_{w,\beta})$ is the hedged portfolio variance either from the optimal portfolio weight (w) or from the optimal hedge ratio (h), and $Var(r_{\text{unhedged}})$ is the variance of the unhedged position between variables i and j. HE_i is the percentage reduction in the variance of unhedged positions where the higher this ratio is, the larger the risk reduction.

3.3 | Descriptive analysis

The descriptive statistics for each logarithmic return series are presented in Table 1, adding further statistical support to the increase in the volatility of all indices during the war relative to the prewar period. All indices in the prewar period had a negative return due to the COVID-19 pandemic, except gold in both markets and ESG in the emerging market only. During the war, a negative return was observed for all indices and in both markets.

The average values of the prewar indices show the superiority of gold in emerging countries and developed countries, followed by ESG in emerging countries. FinTech in emerging markets yields the lowest average return. During the war, gold in developed markets has the best performance, while FinTech in emerging countries continues to yield the lowest performance. In both periods, the renewable energy index in developed countries witness the highest volatility, while ESG has the lowest volatility in emerging countries in the prewar period and developed countries during the war. While FinTech, renewable energy in both markets and ESG and MSCI in emerging countries have positive skewness in both periods, ESG and MSCI in developed countries have negative skewness in both periods. However, gold in both markets changes its skewness from positive to negative, indicating significant negative values during the

TABLE 1 Descriptive statistics.

	Developed (September 1, 2021–February 23, 2022)					Emerging (May 8, 2020–February 23, 2022)				
	FinTech	**Energy**	**Gold**	**ESG**	**MSCI**	**FinTech**	**Energy**	**Gold**	**ESG**	**MSCI**
Panel A: Pre-Russian war										
Mean	−0.00032	−0.00209	0.00102	−0.00013	−0.00024	−0.00276	−0.00035	0.00202	0.00000	−0.00026
SD	0.00837	0.02470	0.01593	0.00807	0.00848	0.01520	0.01812	0.01978	0.00797	0.00806
Skewness	0.015	0.238	0.494**	−0.148	−0.121	0.378*	0.125	0.174	0.13	0.102
Kurtosis	−0.063	0.665	0.739	−0.028	−0.009	0.512	−0.016	0.856*	0.136	0.094
ERS	−4.033***	−3.073***	−3.754***	−4.583***	−4.420***	−4.236***	−2.144**	−2.504**	−4.420***	−4.454***
Panel B: During the Russian war (February 24, 2022—May 11, 2022)										
Mean	−0.00177	−0.00154	−0.00135	−0.00148	−0.00158	−0.00635	−0.00272	−0.00443	−0.00323	−0.00318
SD	0.01420	0.03473	0.01823	0.01388	0.01426	0.03340	0.02144	0.02488	0.01750	0.01639
Skewness	0.008	0.671**	−0.630*	−0.056	−0.064	1.569***	0.383	−0.046	0.232	0.443
Kurtosis	−0.306	1.200*	0.538	−0.361	−0.296	4.934***	1.170*	−0.853*	1.458**	1.841**
ERS	−2.595***	−0.383	−2.661***	−2.549**	−2.558**	−1.832*	−2.464***	−2.775***	−2.21***	−2.219***

Note: This table reports the descriptive statistics of the returns.

Abbreviation: ERS, the Elliot-Rothenberg-Stock unit root test.

***, **, and * indicate the statistical significance, respectively, at 1%, 5%, and 10% levels.

war. To test for the existence of a unit root in the return series, the Elliott–Rothenberg–Stock (ERS) method tests the null hypothesis of a unit root versus the alternative of no unit root in the stock returns series. The results presented in Table 1 show that the null hypothesis was rejected at the 5% significance level for all series and, therefore, integrated of order zero I(0).

4 | RETURN CONNECTEDNESS

4.1 | Static average dynamic connectedness

4.1.1 | Connectedness between developed indices

Table 2 summarizes the average full sample return spillover index for the developed markets obtained from the TVP-VAR model. To investigate the impact of an exogenous shock on the dependencies, we split the whole sample period into two subperiods: (a) the pre-Russian war period (May 8, 2020, or September 1, 2021, to February 23, 2022) and (b) a Russian war period (February 24, 2022, to May 11, 2022). Table 2 clearly shows that TCI increases significantly from 55.89% to 62.20%, supporting the financial literature that dependencies increase during a crisis (Cepoi, 2020; Zhang et al., 2020). Looking at the directional spillover in Table 2, several results emerge. First, while FinTech's and conventional equity's transmissions decrease from 81.24% and 79.31% to 79.0% and 78.55%, respectively, renewable energy and ESG transmissions increase from 31.65% and 69.02% to 37.77% and 77.29%. Gold transmission significantly jumps from 18.26% to as high as 38.38%. The highest transmitting sectors are FinTech and MSCI in both periods, while the least transmitting sector is gold in the prewar and renewable energy during the war. Thus, FinTech is driving market risk in developed countries in both periods, which is not surprising given their importance in today's investment. Second, when looking at the connectedness "FROM," the Russian war increases the values for all indices. FinTech receives the most from the system with 69.55% and 71.83% in both periods. However, gold is the sector that receives the least from the system, with only 24.88% in the prewar period, jumping to 43.31% during the war. Finally, the last column shows the net connectedness or the difference between connectedness "TO" and connectedness "FROM." The results show that FinTech, ESG, and MSCI maintain their role as the main transmitters in both periods, with a decrease in magnitude for both FinTech and MSCI. However, ESG increases its role as a net transmitter from 3.56% to 6.52%. Gold and renewable energy kept their role as net receivers in both periods. Thus, FinTech, ESG, and MSCI are driving the market, whereas gold and renewable energy are driven by the market in developed countries in both markets. These findings indicate that the Russian war only increased the connectedness among these indices, without introducing a wide change across the indices among developed markets as their roles as transmitters/receivers were maintained.

Figure 2 displays the network of the directional pairwise connectedness level in both periods, with several changes between the two periods. For instance, in the prewar period, there is a pairwise connectedness between ESG and MSCI and between ESG and FinTech, which faded during the war. Moreover, the war creates a connectedness between renewable energy and gold. Interestingly, there is no connection between FinTech and MSCI in both periods.

TABLE 2 Total connectedness index between developed markets indices.

	DEV.FINTECH	DEV.ENERGY	DEV.GOLD	DEV.ESG	DEV.MSCI	FROM others
(a) Pre-Russian war (September 1, 2021, to February 23, 2022)						
DEV.FINTECH	30.45	10.62	5.39	23.84	29.7	69.55
DEV.ENERGY	17.48	49.8	3.19	13.02	16.52	50.20
DEV.GOLD	7.54	2.49	75.12	7.95	6.9	24.88
DEV.ESG	26.07	8.3	4.88	34.55	26.2	65.45
DEV.MSCI	30.15	10.24	4.79	24.21	30.61	69.39
TO others	81.24	31.65	18.26	69.02	79.31	279.47
Inc. own	111.69	81.44	93.38	103.56	109.92	TCI
Net	11.69	−18.56	−6.62	3.56	9.92	55.89
(b) During the Russian war (February 21, 2022, to May 11, 2022)						
DEV.FINTECH	28.17	8.09	7.31	28.21	28.22	71.83
DEV.ENERGY	13.11	46.17	17.25	11.31	12.17	53.83
DEV.GOLD	9.47	15.76	56.69	8.94	9.14	43.31
DEV.ESG	28.29	6.7	6.76	29.23	29.02	70.77
DEV.MSCI	28.14	7.22	7.06	28.82	28.75	71.25
TO others	79	37.77	38.38	77.29	78.55	310.99
Inc. own	107.17	83.94	95.07	106.52	107.31	TCI
Net	7.17	−16.06	−4.93	6.52	7.31	**62.20**

Note: This table provides an overview of the level of connetedness between developed market indices in the pre-Russian war in Panel (a) and during the Russian war in Panel (b). The "FROM" column indicates the total amount of directional connectedness flowing from all other markets to market *i*, while the "TO" row shows the total amount of directional connectedness flowing to all other markets from market *j*. The "net" row displays the overall net pairwise directional connectedness (the difference between "TO" and "FROM"). The element in bold at the bottom-right corner of the table represents the total connectedness, which is equal to the mean "FROM" connectedness or the mean "TO" connectedness.

Abbreviation: TCI, total connectedness index.

4.1.2 | Connectedness between emerging indices

Moving to the emerging markets, Table 3 summarizes the spillover index for the five indices in emerging countries. The results show that, like the developed markets, TCI increases, but more significantly, from 54.03% to 67.82%. However, the results when looking at the directional spillover are different from the ones obtained in Table 2. Looking at the connectedness "TO," the Russian war increases the transmission power of all indices. FinTech slightly increases from 53.7% to 56.14%, while ESG and MSCI transmissions increase from 83.59% and 82.78% to 93.14% and 89.82%, respectively. Moreover, gold and renewable energy transmissions significantly increase from 17.37% and 32.7% to 41.81% and 58.16%. The main transmitters of shocks are MSCI and ESG in both periods, while the least transmitting asset is gold in both periods. Thus, ESG is driving market risk in emerging countries. Considering connectedness "FROM" the Russian war increases the values of all indices. ESG

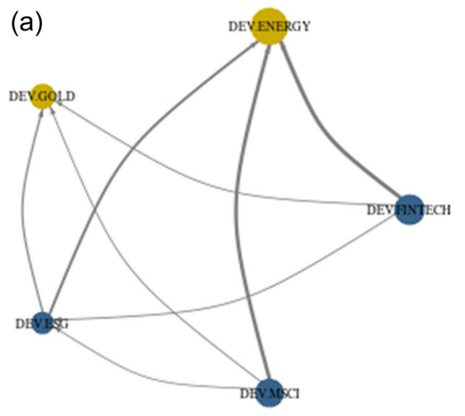


FIGURE 2 Pairwise network connectedness—developed market. Yellow (blue) nodes illustrate the net receiver (transmitter) of shocks: (a) prewar (b) during the war. The size of nodes represents weighted average net total directional connectedness.

and MSCI are the main receivers during both periods, while the least receiver is gold in both periods. However, the value of gold jumps from 33.61% to 58.61%, indicating the importance of gold during the crisis in emerging countries. As for net connectedness, the results show that all indices kept their role with a change in magnitude. For example, MSCI and ESG indices are the main net transmitters with an increase in their magnitude during the war, and FinTech acts as a receiver of shocks with an increase in the magnitude. Thus, during the war, ESG and MSCI are driving the market in emerging countries, whereas FinTech, renewable energy, and gold are driven by the market in such countries.

Again, these findings indicate that the Russian war did change the role of the indices as transmitters/receivers. Interestingly, while FinTech in developed countries is driving the market, it is driven by the market in emerging countries.

The pairwise network connectedness in Figure 3 shows that FinTech, gold, and renewable energy are net receivers in both periods. The pairwise connectedness between renewable energy and FinTech faded during the war. Interestingly, there is no connection between ESG and MSCI in both periods.

4.1.3 | Connectedness between developed and emerging indices

Given that emerging economies are playing an important role in the global financial markets, there is a need to study their connectedness with developed markets, as the former is growing much faster. Thus, Table 4 summarizes the spillover index for the 10 indices divided into two panels. Again, the results support the finding that the Russian war increased the TCI from 71.35% to 80.49%. The high level of connectedness indicates that these markets are not independent of each other. Other interesting results also emerge; while developed markets represented by FinTech and ESG are the main transmitters in the prewar period with 93.52% and 93.08%, respectively, emerging markets represented by MSCI and ESG become the highest transmitters of shocks during the war with 118.77% and 116.84%. The lowest transmitter index is gold in the developed markets in the pre-Russian war and ESG in the developed markets during the war. Moreover, the Russian war increases the transmission power of all indices in

TABLE 3 Total connectedness index between emerging markets indices.

	EMG.FINTECH	EMG.ENERGY	EMG.GOLD	EMG.ESG	EMG.MSCI	FROM others
(a) Pre-Russian war (May 8, 2020, to February 23, 2022)						
EMG.FINTECH	40.99	8.88	4.19	22.56	23.38	59.01
EMG.ENERGY	11.51	54.55	2.85	15.68	15.4	45.45
EMG.GOLD	6.01	3.68	66.39	12.56	11.36	33.61
EMG.ESG	17.84	10.1	5.14	34.28	32.64	65.72
EMG.MSCI	18.34	10.04	5.19	32.77	33.66	66.34
TO others	53.7	32.7	17.37	83.59	82.78	270.13
Inc. own	94.68	87.25	83.76	117.86	116.44	TCI
Net	−5.32	−12.75	−16.24	17.86	16.44	54.03
(b) During the Russian war (February 24, 2022, to May 11, 2022)						
EMG.FINTECH	32.16	11.3	9.09	23.88	23.58	67.84
EMG.ENERGY	12.99	30.42	11.62	23.38	21.59	69.58
EMG.GOLD	11.03	12.08	41.39	18	17.5	58.61
EMG.ESG	15.75	17.91	10.48	28.7	27.15	71.3
EMG.MSCI	16.37	16.88	10.62	27.88	28.26	71.74
TO others	56.14	58.16	41.81	93.14	89.82	339.08
Inc. own	88.3	88.58	83.2	121.84	118.08	TCI
Net	−11.7	−11.42	−16.8	21.84	18.08	67.82

Note: This table provides an overview of the level of connectedness between emerging maket indices in the pre-Russian war in Panel (a) and during the Russian war in Panel (b). The "FROM" column indicates the total amount of directional connectedness flowing from all other markets to market *i*, while the "TO" row shows the total amount of directional connectedness flowing to all other markets from market *j*. The "net" row displays the overall net pairwise directional connectedness (the difference between "TO" and "FROM"). The element in bold at the bottom-right corner of the table represents the total connectedness, which is equal to the mean "FROM" connectedness or the mean "TO" connectedness.

Abbreviation: TCI, total connectedness index.

emerging countries; however, it decreases the power of the majority of the indices in developed countries. Looking at "FROM," the developed markets represented by FinTech and MSCI are the main receivers during both periods, while gold in the emerging markets is the least receiver. As for net connectedness, the war changes the role played by the majority of the indices. The FinTech, MSCI, and ESG indices in the developed markets flipped their role by becoming net receivers during the war. On the other side, FinTech, MSCI, and ESG in emerging countries are net transmitters in both periods with an increased magnitude. The renewable energy index keeps its role as a net receiver in both periods, with a more significant impact in emerging countries. Finally, gold is a main receiver in developed countries, but becomes a main transmitter in emerging markets during the war. The results indicate that the war has a huge impact on the role played by some assets, mainly in emerging markets.

Figure 4 displays the pairwise network connectedness of all indices, which clearly shows several changes between the two periods in terms of transmission/receiver, the size of the node,

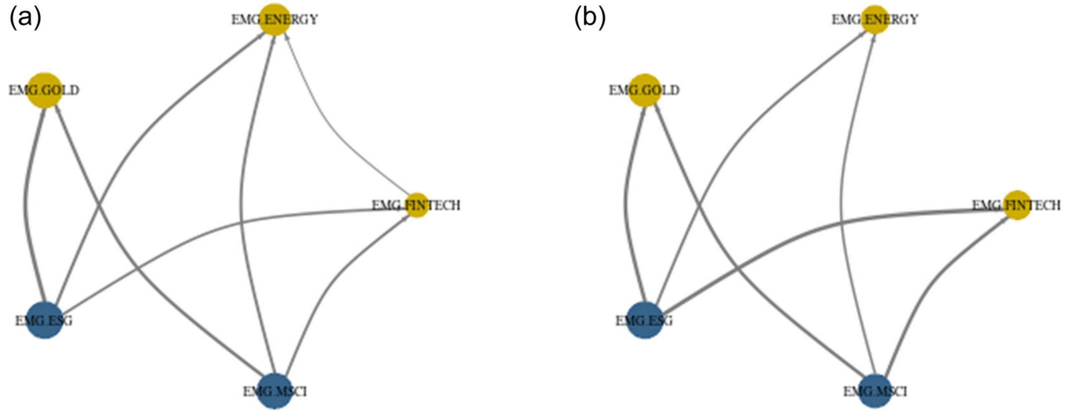


FIGURE 3 Pairwise network connectedness—emerging market. Yellow (blue) nodes illustrate the net receiver (transmitter) of shocks: (a) prewar (b) during the war. The size of nodes represents the weighted average net total directional connectedness.

and the direction of the connectedness. The node of FinTech in emerging countries is bigger during the war, indicating the growing role of this asset as a net transmitter during this period. Interestingly, the connectedness between gold and renewable and between gold and FinTech in developed markets faded during the war period, while a connection was created between FinTech in both markets. The war created more connectedness between those assets.

4.2 | Dynamic connectedness

The static spillover index shown in Tables 2–4 may not capture the evolution of the interdependence between markets over time. Moreover, to determine whether the connectedness between these indices varied through time and how it was affected by the war, we estimated the different time-varying connectedness measures for the developed indices, emerging indices, and all indices in Figure 5. Figure 5a shows a large fluctuation in these indices during the sample period. The total connectedness index was relatively high at the start of the period in all panels. Looking at Figure 5a, TCI, in the prewar period, displays a downward and fluctuating trend, reaching its trough of 49.23% on September 24, 2020. However, it significantly increases at the outbreak, exceeding 60% on February 25, 2022, and 74% on March 3, 2022, before resuming its downward trend. During the war, TCI fluctuates between 57% and 75%. These results are expected, as it is well known that stock markets are interlinked and that a crisis period might increase their linkage (Mokni & Mansouri, 2017). A similar trend is observed in emerging markets. In Figure 5b, the TCI of emerging indices has had a downward trend since May 2020, falling below 60% on June 29, 2020, and then fluctuating between 50% and 55%, before jumping at the outbreak of the war exceeding 75% on March 4, 2022. After the war, TCI fluctuates between 64% and 75%. The results indicate that the war had a bigger impact on the TCI of emerging countries. Finally, 5c shows that TCI has a slightly downward trend during the prewar period. However, it suddenly jumps during the first days of the war, to reach 85%, fluctuating between 80% and 85%, before resuming its previous

TABLE 4 Total connectedness index between all indices.

	DEV. FinTech	DEV. Energy	DEV. Gold	DEV. ESG	DEV. MSCI	EMG. FinTech	EMG. Energy	EMG. Gold	EMG. ESG	EMG.MSCI	FROM others
(a) Pre-Russian war (May 8, 2020, to February 23, 2022)											
DEV.FINTECH	18.95	9	1.7	18.94	18.88	10.26	2.9	1.07	8.86	9.45	81.05
DEV.ENERGY	12.04	26.83	1.07	10.63	11.54	12.7	6.43	1.8	8.36	8.6	73.17
DEV.GOLD	8.01	2.66	45.24	10.44	9.23	2.67	1.23	15.39	2.2	2.93	54.76
DEV.ESG	19.08	8.13	2.15	20.15	19.46	9.42	2.64	1.21	8.52	9.25	79.85
DEV.MSCI	19.22	8.81	1.96	19.68	19.52	9.76	2.6	1.15	8.37	8.92	80.48
EMG.FINTECH	10.99	9.46	1.06	10.05	10.19	21.06	6.34	2.14	13.86	14.86	78.94
EMG.ENERGY	4.14	9.37	1.49	3.58	3.59	9.61	38.76	3.66	12.6	13.2	61.24
EMG.GOLD	2.68	5.38	12.02	3.48	3.05	4.84	2.66	52.55	**6.93**	**6.41**	**47.45**
EMG.ESG	8.64	7.85	1.39	8.01	7.9	12.76	7.67	2.83	21.86	21.08	78.14
EMG.MSCI	8.72	7.53	1.44	8.26	7.9	13.3	7.91	2.68	20.67	21.6	78.4
TO others	93.52	68.17	24.26	93.08	91.73	85.33	40.4	31.93	90.36	94.69	713.48
Inc. own	112.47	95.01	69.51	113.23	111.25	106.39	79.15	84.48	112.22	116.29	TCI
Net	12.47	−4.99	−30.49	13.23	11.25	6.39	−20.85	−15.52	12.22	16.29	71.35
(b) During the Russian war (February 24, 2022, to May 11, 2022)											
DEV.FINTECH	13.14	9.52	7.47	12.14	12.4	10.99	3.94	7.36	11.18	11.86	86.86
DEV.ENERGY	8.31	20.31	10.83	6.63	7.09	12.44	4.11	10.43	9.94	9.91	79.69
DEV.GOLD	7.26	11.67	21	6.17	6.4	10.38	3.7	16.87	8.13	8.42	79
DEV.ESG	13.83	8.73	7.45	13.34	13.47	10.04	3.84	7.14	10.74	11.43	86.66
DEV.MSCI	13.54	8.97	7.53	12.9	13.1	10.34	3.89	7.38	10.86	11.49	86.9

TABLE 4 (Continued)

	DEV. FinTech	DEV. Energy	DEV. Gold	DEV. ESG	DEV. MSCI	EMG. FinTech	EMG. Energy	EMG. Gold	EMG. ESG	EMG.MSCI	FROM others
EMG.FINTECH	7.15	10.44	4.67	5.39	5.89	23.19	5.61	7.28	15.01	15.37	76.81
EMG.ENERGY	3.86	5.6	6.08	2.67	2.93	11.74	22.8	10.86	16.98	16.47	77.2
EMG.GOLD	4.07	9.9	11.28	2.81	3.04	10.96	7.52	24.78	13.09	12.56	75.22
EMG.ESG	4.1	6.78	4.59	2.84	3.09	12.48	12.78	10.41	21.67	21.27	78.33
EMG.MSCI	4.17	7.03	5.26	2.81	3.08	12.6	12.43	9.98	20.93	21.71	78.29
TO others	66.3	78.63	65.15	54.37	57.4	101.96	57.81	87.71	116.84	118.77	804.94
Inc. own	79.44	98.95	86.15	67.71	70.5	125.16	80.61	112.49	138.52	140.48	TCI
Net	−20.56	−1.05	−13.85	−32.29	−29.5	25.16	−19.39	12.49	38.52	40.48	80.49

Note: This table provides an overview of the level of connectedness between all indices in the pre-Russian war in Panel (a) and during the Russian war in Panel (b). The "FROM" column indicates the total amount of directional connectedness flowing from all other markets to market i, while the "TO" row shows the total amount of directional connectedness flowing to all other markets from market j. The "net" row displays the overall net pairwise directional connectedness (the difference between "TO" and "FROM"). The element in bold at the bottom-right corner of the table represents the total connectedness, which is equal to the mean "FROM" connectedness or the mean "TO" connectedness.

Abbreviation: TCI, total connectedness index.

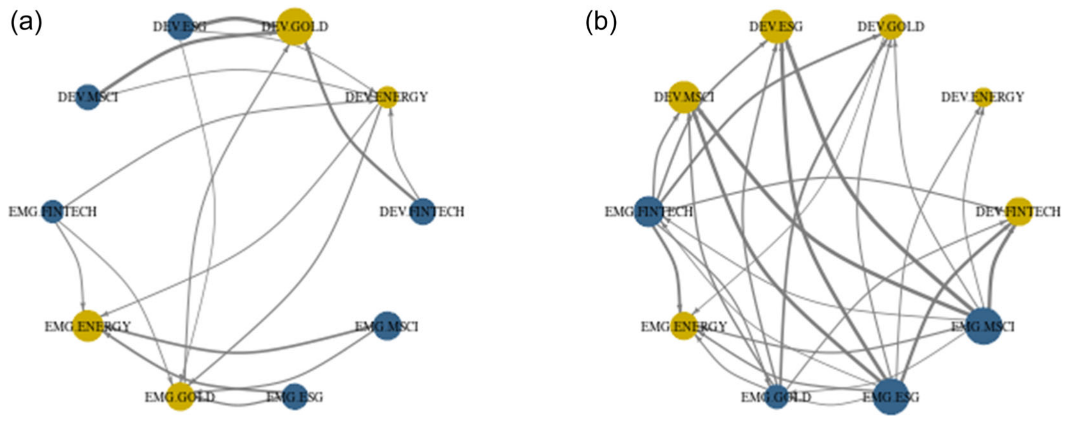


FIGURE 4 Pairwise network connectedness—all market indices. Yellow (blue) nodes illustrate the net receiver (transmitter) of shocks: (a) prewar (b) during the war. The size of nodes represents the weighted average net total directional connectedness.

downward trend. Overall, this high interconnectedness is indicative that there is a substantial market risk associated with those indices.

4.3 | Net connectedness

To further emphasize the time-varying behavior of connectedness, Figure 6 displays the dynamics of the net total directional connectedness measures. The purpose is to see whether an asset is a persistent net transmitter or a net receiver. While a positive value indicates a net transmitter, a negative value refers to a net receiver.

In Figure 6a for developed countries, the results show that FinTech and MSCI are persistent net transmitters of spillover in the prewar period. These results emphasize the role of FinTech in the contagion transmission in developed markets. However, gold and renewable energy are less attractive for investors as they are net receivers of shocks, indicating that exogenous influences primarily drive their returns. The role of ESG is minimal, as its net connectedness is minimal. However, the story is different during the war. Although FinTech, ESG, and MSCI remain net transmitters, they witness a jump in their transmission role during the first half of March, indicating their transmission power during turbulent periods. Renewable energy shows a persistent and prolonged role as a net receiver, after March 1, 2022, while gold shows a fluctuating role during the war, changing from a net transmitter to a net receiver several times. Interestingly, these ESG, FinTech, and MSCI indices show a similar pattern, reaching their maximum at the same point.

In Figure 6b for emerging countries, the role of FinTech is very minimal in the prewar period, while ESG and MSCI are mainly net transmitters. Renewable energy and gold are generally the main receivers, despite being net transmitters at the beginning of the period. The war significantly changed the role played by some indices. The FinTech acts as a net transmitter of spillover from the outbreak of war until May 15, before becoming the main receiver. ESG and MSCI maintain their role as net transmitters, although MSCI's role faded during the first week of March. Renewable energy was a net receiver before the war, with an

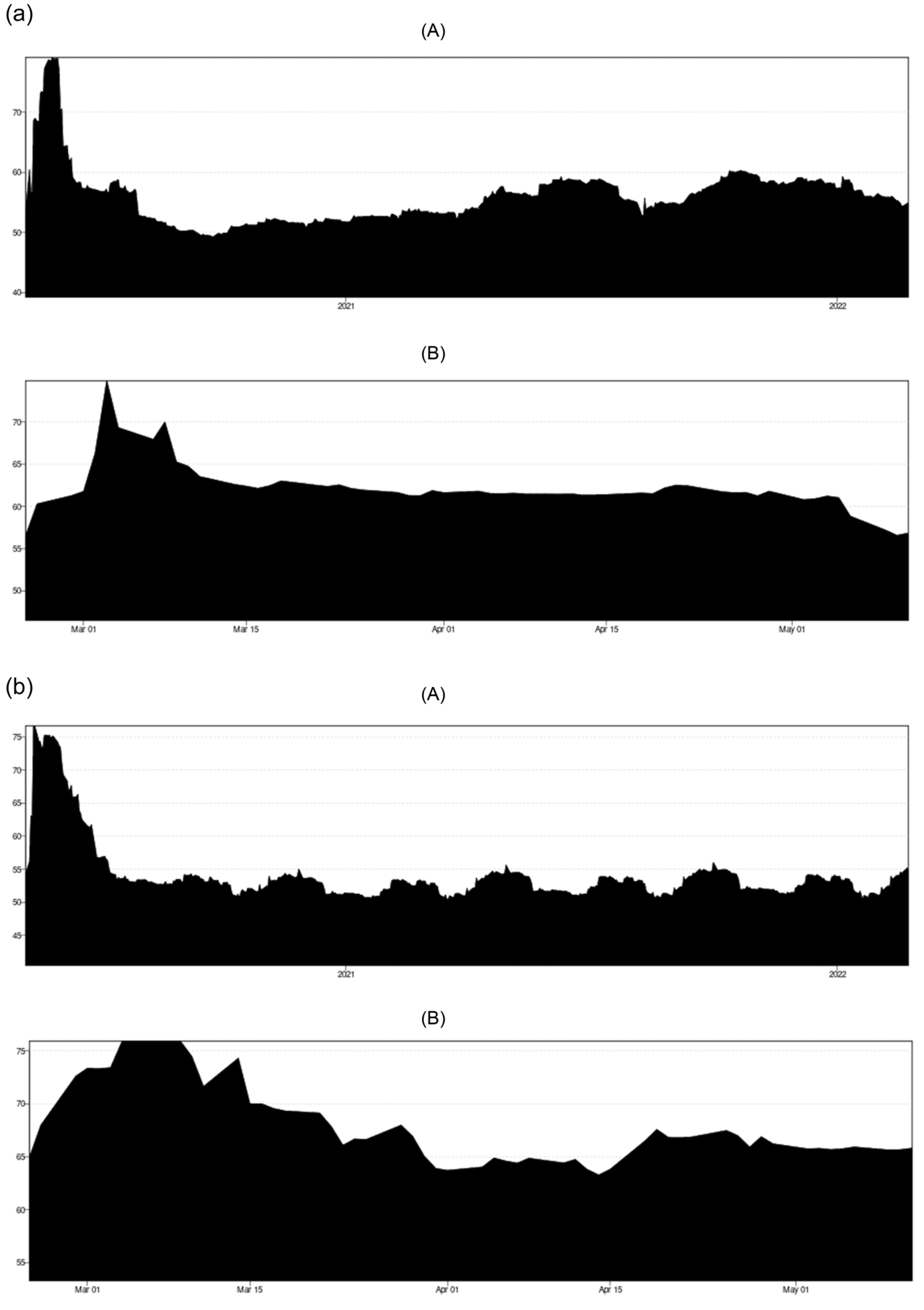


FIGURE 5 Dynamic total connectedness. The dynamic total connectedness between indices (a) in developed countries, (b) in emerging countries, and (c) all indices are denoted. In each panel, the dynamic connectedness is presented (A) prewar and (B) during the war.

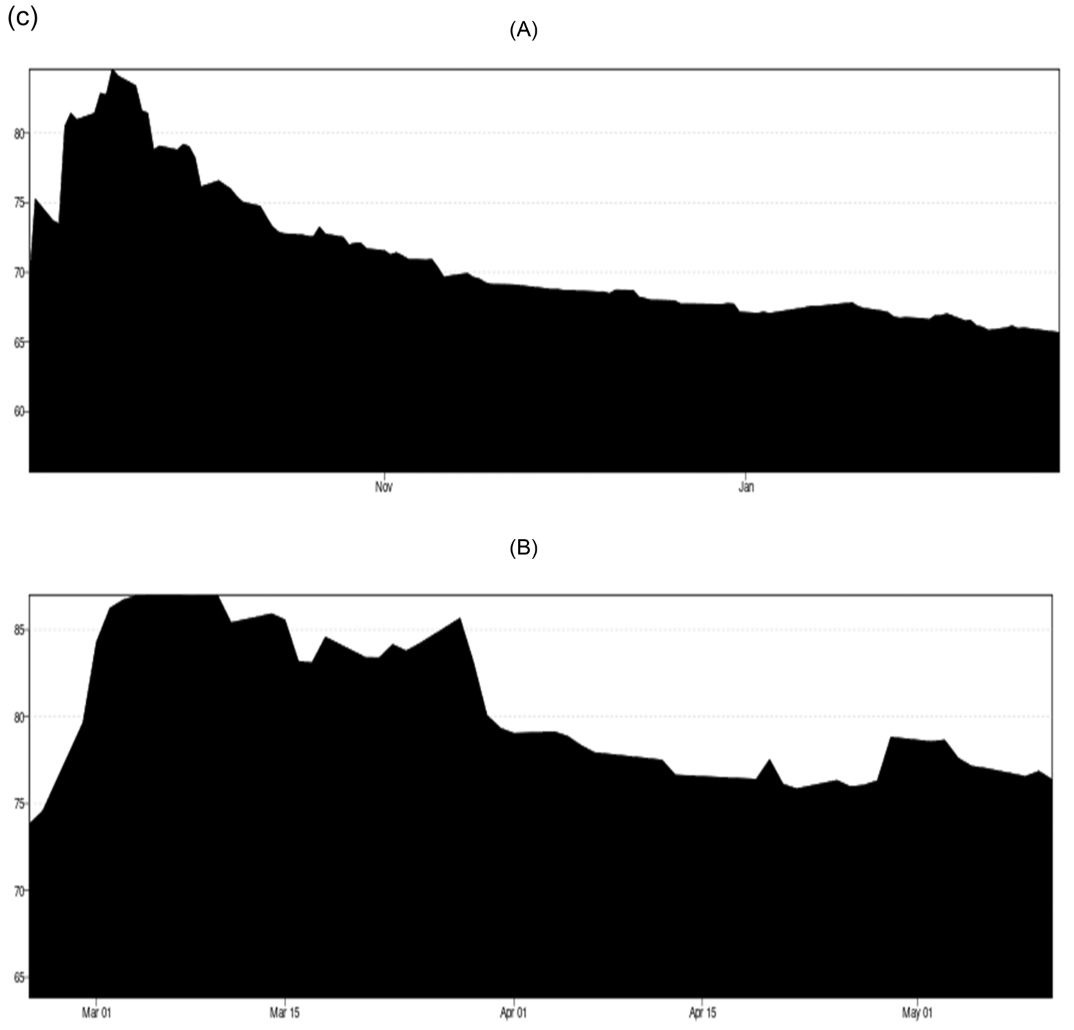


FIGURE 5 (Continued)

increase in its magnitude during the war during the first half of March. Finally, gold's role as a main receiver increased during the war.

In Figure 6c, interesting results emerge when the indices in developed countries are merged with those in emerging countries. In the prewar period, the role of the same index is the same regardless of whether it represents developed or emerging countries. For example, MSCI and ESG are net transmitters in the prewar period in both markets, while renewable energy and gold are net receivers in both markets. In the prewar period, FinTech in developed markets play a much more significant role than the same index in emerging countries. During the war, the role of the same index depends on whether it represents developed or emerging countries. Starting with FinTech, MSCI, and ESG, they become net receivers in developed markets, but net transmitters in emerging markets. Renewable energy has a fluctuating role in developed countries, but is a net receiver in both markets. Similarly, gold plays a fluctuating role, changing its sign more than one time.

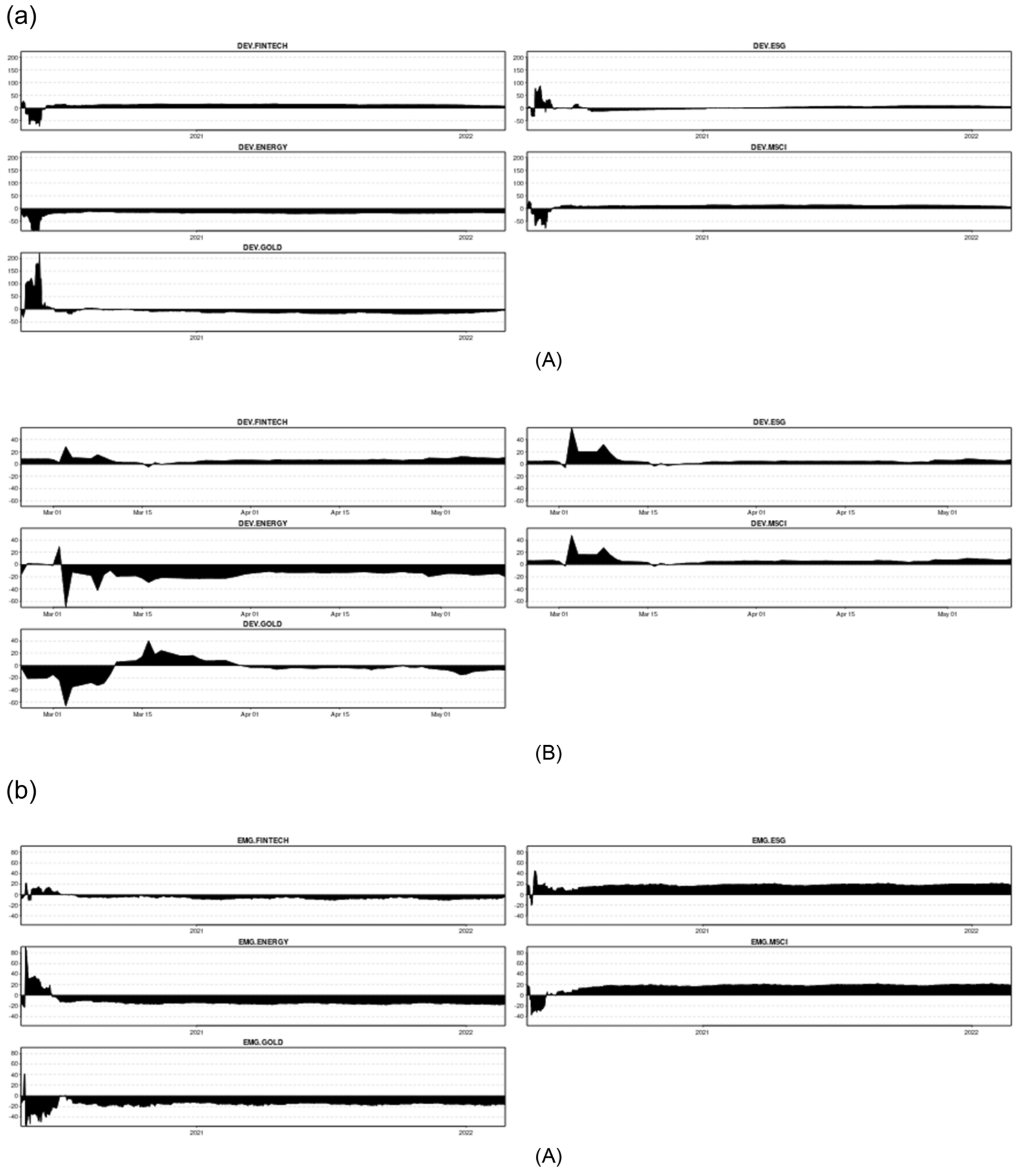
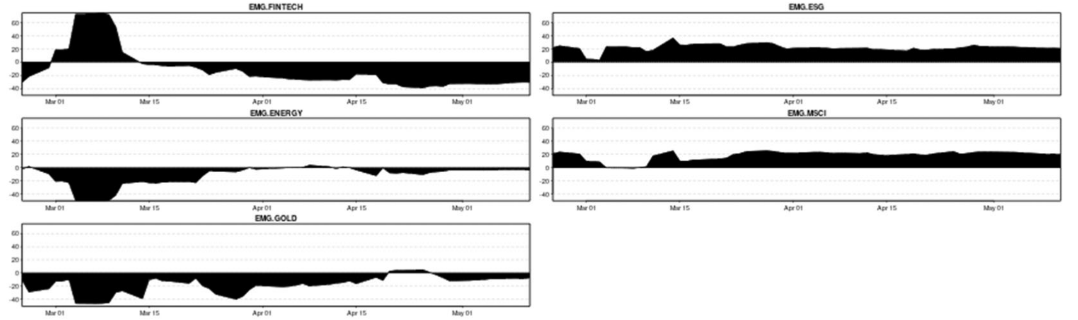


FIGURE 6 Dynamic net total directional connectedness. The dynamic net connectedness of each index (a) in developed countries, (b) in emerging countries and (c) for all indices are denoted. In each panel, the net connectedness is presented (A) prewar and (B) during the war. If the spillover index is positive (negative), the hedge market is the net information transmitter (receiver) of return spillovers.

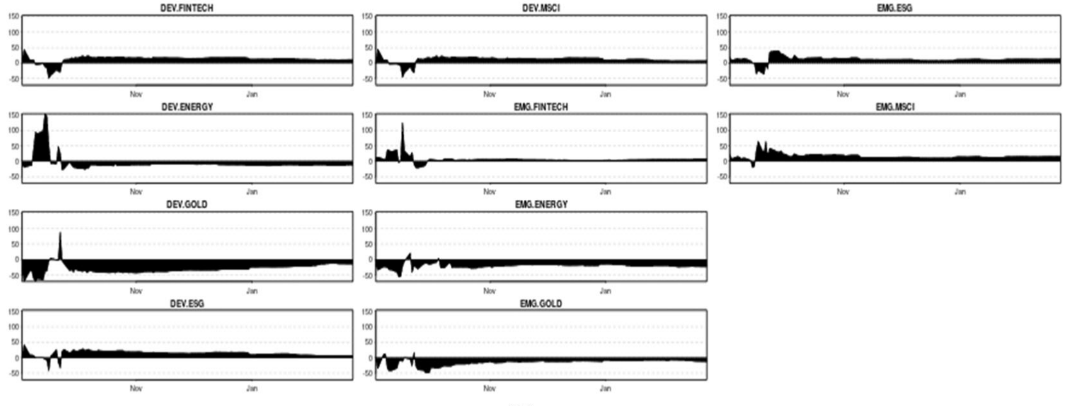
5 | HEDGE RATIOS AND PORTFOLIO WEIGHTS

Given the high connectedness between these indices, we proceeded to examine the implications for risk management and portfolio diversification by constructing the optimal hedge ratios and the portfolio weights. These weights strategies are estimated based on the conditional covariances between assets using the DCC-GARCH t-Copula model.

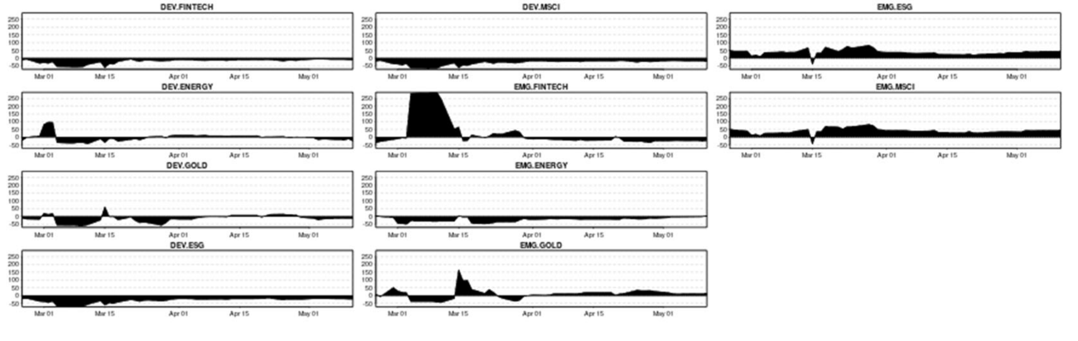


(B)

(c)



(A)



(B)

FIGURE 6 (Continued)

The optimal hedge ratios are constructed by assuming that investors are taking a long (short) position in one of the following indices when the future volatility is expected to be higher (lower) compared to the current volatility level. Investors might hedge their long or short positions. Volatilities are calculated using GARCH (1,1), assuming a normal distribution. Table 5 reports the optimal hedge ratio for a USD 1 long position in one of the asset's volatilities and a β_{jit} short position in the volatility of each of the other indices. Moreover, Table 5 displays the standard deviation of the hedge ratios and the HE and its statistical significance level.

TABLE 5 Hedging ratios among indices (long/short).

DEV-DEV	Mean	SD	HE (%)	*p* Value	EMG-EMG	Mean	SD	HE (%)	*p* Value
DEV.ENERGY/DEV.FINTECH	1.56	0.33	27	0.050	EMG.ENERGY/EMG.FINTECH	0.41	0.14	12	0.440
DEV.GOLD/DEV.FINTECH	0.37	0.11	6	0.700	EMG.GOLD/EMG.FINTECH	0.32	0.1	3	0.840
DEV.ESG/DEV.FINTECH	0.96	0.08	97	**0.000**	EMG.ESG/EMG.FINTECH	0.36	0.06	37	**0.000**
DEV.FINTECH/DEV.ENERGY	0.19	0.04	30	**0.020**	EMG.MSCI/EMG.FINTECH	0.36	0.06	37	**0.000**
DEV.GOLD/DEV.ENERGY	0.14	0.03	5	0.770	EMG.FINTECH/EMG.ENERGY	0.43	0.24	15	0.310
DEV.ESG/DEV.ENERGY	0.17	0.04	25	0.070	EMG.GOLD/EMG.ENERGY	0.29	0.06	6	0.690
DEV.MSCI/DEV.ENERGY	0.19	0.04	28	**0.040**	EMG.ESG/EMG.ENERGY	0.34	0.13	32	**0.010**
DEV.FINTECH/DEV.GOLD	0.14	0.05	7	0.660	EMG.MSCI/EMG.ENERGY	0.32	0.13	31	**0.020**
DEV.ENERGY/DEV.GOLD	0.43	0.1	7	0.650	EMG.FINTECH/EMG.GOLD	0.27	0.12	8	0.610
DEV.ESG/DEV.GOLD	0.12	0.05	5	0.760	EMG.ENERGY/EMG.GOLD	0.24	0.04	6	0.680
DEV.MSCI/DEV.GOLD	0.13	0.05	5	0.720	EMG.ESG/EMG.GOLD	0.25	0.08	23	0.100
DEV.FINTECH/DEV.ESG	1.02	0.08	97	**0.000**	EMG.MSCI/EMG.GOLD	0.25	0.08	23	0.090
DEV.ENERGY/DEV.ESG	1.47	0.37	20	0.170	EMG.FINTECH/EMG.ESG	1.17	0.21	41	**0.000**
DEV.GOLD/DEV.ESG	0.32	0.11	4	0.780	EMG.ENERGY/EMG.ESG	1.06	0.29	46	**0.000**
DEV.MSCI/DEV.ESG	1.03	0.03	99	**0.000**	EMG.GOLD/EMG.ESG	0.98	0.24	19	0.190
DEV.FINTECH/DEV.MSCI	0.98	0.06	99	**0.000**	EMG.MSCI/EMG.ESG	0.96	0.04	96	**0.000**
DEV.ENERGY/DEV.MSCI	1.5	0.35	23	0.090	EMG.FINTECH/EMG.MSCI	1.23	0.22	42	**0.000**
DEV.GOLD/DEV.MSCI	0.34	0.11	5	0.760	EMG.ENERGY/EMG.MSCI	1.06	0.29	41	**0.000**
DEV.ESG/DEV.MSCI	0.96	0.02	99	**0.000**	EMG.GOLD/EMG.MSCI	1.02	0.25	20	0.160
DEV-EMG					**EMG-DEV**				
DEV.FINTECH/EMG.FINTECH	0.37	0.07	49	**0.000**	EMG.FINTECH/DEV.FINTECH	1.51	0.47	51	**0.000**

(Continues)

TABLE 5 (Continued)

DEV-EMG					EMG-DEV				
DEV.ENERGY/ EMG.FINTECH	0.84	0.23	17	0.230	EMG.ENERGY/DEV.FINTECH	0.64	0.2	7	0.600
DEV.GOLD/EMG.FINTECH	0.21	0.07	1	0.950	EMG.GOLD/DEV.FINTECH	0.26	0.11	1	0.990
DEV.ESG/EMG.FINTECH	0.34	0.08	42	**0.000**	EMG.ESG/DEV.FINTECH	0.58	0.13	19	0.580
DEV.MSCI/EMG.FINTECH	0.36	0.08	44	**0.000**	EMG.MSCI/DEV.FINTECH	0.57	0.13	19	0.660
DEV.FINTECH/ EMG.ENERGY	0.16	0.05	8	0.590	EMG.FINTECH/DEV.ENERGY	0.43	0.21	32	**0.020**
DEV.ENERGY/EMG.ENERGY	0.42	0.09	9	0.560	EMG.ENERGY/DEV.ENERGY	0.21	0.04	6	0.530
DEV.GOLD/EMG.ENERGY	0.11	0.04	3	0.860	EMG.GOLD/DEV.ENERGY	0.24	0.04	8	0.720
DEV.ESG/EMG.ENERGY	0.14	0.05	6	0.700	EMG.ESG/DEV.ENERGY	0.13	0.05	8	0.370
DEV.MSCI/EMG.ENERGY	0.15	0.05	6	0.680	EMG.MSCI/DEV.ENERGY	0.14	0.05	9	0.300
DEV.FINTECH/EMG.GOLD	0.05	0.03	1	0.950	EMG.FINTECH/DEV.GOLD	0.33	0.15	7	0.840
DEV.ENERGY/EMG.GOLD	0.41	0.06	10	0.480	EMG.ENERGY/DEV.GOLD	0.17	0.05	3	0.910
DEV.GOLD/EMG.GOLD	0.37	0.04	24	0.090	EMG.GOLD/DEV.GOLD	0.69	0.06	26	0.580
DEV.ESG/EMG.GOLD	0.03	0.03	0	0.990	EMG.ESG/DEV.GOLD	0.18	0.07	8	0.940
DEV.MSCI/EMG.GOLD	0.04	0.03	0	0.980	EMG.MSCI/DEV.GOLD	0.19	0.07	9	0.920
DEV.FINTECH/EMG.ESG	0.46	0.08	22	0.110	EMG.FINTECH/DEV.ESG	1.45	0.46	45	**0.000**
DEV.ENERGY/EMG.ESG	0.87	0.22	4	0.780	EMG.ENERGY/DEV.ESG	0.58	0.2	5	0.680
DEV.GOLD/EMG.ESG	0.38	0.11	5	0.750	EMG.GOLD/DEV.ESG	0.16	0.1	0	1.000
DEV.ESG/EMG.ESG	0.41	0.08	17	0.230	EMG.ESG/DEV.ESG	0.54	0.13	13	0.780
DEV.MSCI/EMG.ESG	0.43	0.08	18	0.220	EMG.MSCI/DEV.ESG	0.54	0.13	14	0.850

TABLE 5 (Continued)

DEV-EMG					EMG-DEV				
DEV.FINTECH/EMG.MSCI	0.48	0.08	21	0.140	EMG.FINTECH/DEV.MSCI	1.43	0.45	47	**0.000**
DEV.ENERGY/EMG.MSCI	0.93	0.23	6	0.700	EMG.ENERGY/DEV.MSCI	0.57	0.19	5	0.710
DEV.GOLD/EMG.MSCI	0.43	0.12	6	0.710	EMG.GOLD/DEV.MSCI	0.17	0.1	0	0.980
DEV.ESG/EMG.MSCI	0.43	0.08	16	0.280	EMG.ESG/DEV.MSCI	0.52	0.12	14	0.780
DEV.MSCI/EMG.MSCI	0.44	0.08	16	0.260	EMG.MSCI/DEV.MSCI	0.51	0.12	14	0.870

Note: The mean is the optimal hedge ratio for a \$1 long position in *j* volatility and a \$$\beta jit$ % short position in the volatility of *i*. Hedging effectiveness (*HE*) is calculated as 1 − (Var$H$/Var$U$) where VarH and VarU are the variances of the hedged and unhedged positions, respectively.

The average hedge ratios range from 0.00 to 1.56, with HE ranging from 0% to 99%. However, the interpretation will focus only on the significant hedge (at 1% significance only), highlighted in bold.

The volatility of FinTech in developed markets can be hedged with a short position in the volatility of four assets, namely, energy in developed markets for USD 0.19, ESG in developed markets for USD 1.02, MSCI in developed markets for USD 0.98, and FinTech in emerging markets for USD 0.37. The HE statistics indicate that risk reduction ranges from 30% to 99%. The most effective strategy is hedging FinTech with MSCI, which is not the most expensive one. Interestingly, FinTech in emerging countries can be used to hedge the volatility of FinTech in developed markets, with a 49% risk reduction.

As for FinTech in emerging countries, its volatility can be hedged with a short position in six indices, namely, ESG emerging with USD 1.17, MSCI emerging with USD 1.23, FinTech developed with USD 1.51, energy developed with USD 0.43, ESG developed with USD 1.45, and MSCI developed with USD 1.43. The HE ranges from 32% to 51%. The most expensive and effective strategy is hedging FinTech in emerging with FinTech in developed.

Moving on to ESG, its volatility in developed countries can be hedged using FinTech developed with USD 0.96 (97% effectiveness), MSCI developed with USD 0.96 (99% effectiveness), and FinTech emerging with USD 0.34 (42% effectiveness). Indeed, ESG developed can be best hedged using MSCI with a risk reduction of 99%. In emerging countries, the volatility of ESG can be only hedged using FinTech and renewable energy in emerging with USD 0.36 and 0.34, respectively. However, the HE is only 37% and 32%. Thus, ESG in developed markets can be better hedged than in emerging markets.

As for MSCI in developed countries, its volatility can be hedged using renewable energy developed with USD 0.19, ESG developed with USD 1.03, and with emerging FinTech with USD 0.36. The most effective strategy is using ESG developed to hedge MSCI with a risk reduction of 99%, but it is a very expensive strategy. The MSCI in emerging countries can be hedged using renewable energy emerging with USD 0.32, FinTech emerging with USD 0.36 cents, and ESG emerging with USD 0.96. Thus, MSCI in emerging countries can be hedged effectively with ESG with a risk reduction of 96%. Interestingly, gold volatility cannot be hedged using these indices and does not provide any risk reduction for any indices. Finally, renewable energy in emerging countries can be hedged using ESG emerging with USD 1.06 (46%) and MSCI emerging with USD 1.06 (41%). Thus, hedging renewable energy in emerging countries is costly and more effective than hedging it in developed markets.

In conclusion, hedging the volatilities of FinTech in developed markets by taking short positions in ESG and MSCI is relatively high (USD 1.02 and USD 0.98), but effective. Similarly, the volatilities of ESG and MSCI in developed markets can be effectively hedged, reaching 99%. ESG in developed markets provides a good hedging opportunity for FinTech and MSCI in developed markets.

The costs of hedging the volatilities of FinTech in emerging countries are also expensive, but less effective. ESG in emerging countries can be hedged more cheaply, but less effectively. Only MSCI in emerging countries can be hedged effectively using ESG emerging.

Thus, the results of the HE of the optimal hedge ratio strategies indicate that the volatility of indices in developed countries can be hedged significantly with the volatility of other indices in developed countries, whereas the volatilities of the same indices in emerging countries cannot be hedged significantly. Gold does not provide any hedging opportunities for any of the considered indices in either market.

Table 6 shows the dynamic optimal portfolio weights of one of the indices in a portfolio with the other index. For developed markets, the HE statistics are significant and relatively high for the portfolios with the volatility of renewable energy; the weights of the renewable energy range from 0.00 to 0.18. The highest HE for the volatility of renewable energy can be reached by constructing a USD 1 portfolio with ESG, investing USD 0.01 in renewable energy, and the remaining USD 0.99 in ESG volatility, with a HE of 87%. As for gold in developed markets, the highest HE is 67%, by investing 24% in gold and 76% in ESG, developed. Moving to emerging countries, the HE is the highest for FinTech, which can be hedged by investing 1% in FinTech and 99% in either ESG or MSCI, achieving a risk reduction of 72% and 74%, respectively. For renewable energy in emerging countries, the highest HE can be achieved by investing 8% in renewable energy and 92% in MSCI. However, this portfolio can only reduce the risk by 59%. Finally, gold in emerging countries can be hedged using MSCI by investing 6% in gold and 94% in MSCI emerging. Thus, hedging renewable energy in developed countries is more efficient than in emerging countries, while gold can be hedged better in emerging countries.

When a portfolio can be used by combining indices between developed and emerging markets, we can see that renewable energy in developed markets can be hedged using FinTech emerging, but it is less efficient than FinTech developed, being 45% efficient rather than 86%. However, including MSCI emerging or ESG emerging with renewable energy developed is 84% and 83% effective, respectively, indicating the important role of MSCI and ESG in both countries to hedge renewable energy developed. Similarly, ESG and MSCI emerging can be included with gold to achieve hedge effectiveness of 60% and 61%, respectively.

With regard to FinTech emerging, this can be better hedged through combination with developed indices such as FinTech (78%), ESG (79%), and MSCI (78%). ESG in emerging can be hedged using developed ESG, FinTech, and MSCI indices. Similarly, renewable energy and gold in emerging markets can be best combined with the same three indices to achieve the best diversification. Therefore, FinTech, ESG, and MSCI in developed countries can provide effective hedging for indices in emerging countries, mainly FinTech, renewable energy, and gold.

6 | FINDINGS

Based on the TVP-VAR model, the spillover intensity was aggravated during the Russia–Ukraine war in the three studied regions. The TCI increased in developed countries from 55.89% to 62.2%, in emerging countries from 54.03% to 67.82%, and in the combined context (developed and emerging) from 71.35% to 80.49%. The combined context pinpoints the increased connectedness before and during the war.

The same results for transmitting/receiving indices were gathered in the prewar period and during the war. In the developed markets, the FinTech, ESG, and MSCI indices were net transmitters, while energy and gold were net receivers. In the emerging markets, ESG and MSCI were net transmitters, while FinTech, energy, and gold were net receivers. In the combined context, FinTech, ESG, and MSCI were net transmitters, while energy and gold were net receivers before the war. During the war, emerging indices such as FinTech, ESG, MSCI, and gold became net transmitters. The developed indices—FinTech, ESG, MSCI, energy, gold—and the emerging energy index turned out to be net receivers. Our findings are in line with Li

TABLE 6 Dynamic optimal portfolios weights.

DEV-DEV					EMG-EMG				
	Mean	**SD**	**HE (%)**	***p* Value**		**Mean**	**SD**	**HE (%)**	***p* Value**
DEV.FINTECH/DEV.ENERGY	1.00	0.01	1	0.970	EMG.FINTECH/EMG.ENERGY	0.51	0.26	46	**0.000**
DEV.FINTECH/ DEV.FINTECH	0.76	0.11	14	0.330	EMG.FINTECH/EMG.GOLD	0.57	0.2	41	**0.000**
DEV.FINTECH/DEV.ESG	0.35	0.47	5	0.720	EMG.FINTECH/EMG.ESG	0.01	0.03	72	**0.000**
DEV.FINTECH/DEV.MSCI	0.53	0.48	1	0.950	EMG.FINTECH/EMG.MSCI	0.01	0.02	74	**0.000**
DEV.ESG/DEV.FINTECH	0.65	0.47	0	1.000	EMG.ESG/EMG.FINTECH	0.99	0.03	−1	0.970
DEV.ESG/DEV.ENERGY	1.00	0.01	1	0.960	EMG.ESG/EMG.ENERGY	0.91	0.2	−13	0.450
DEV.ESG/DEV.FINTECH	0.76	0.12	13	0.360	EMG.ESG/EMG.GOLD	0.93	0.14	1	0.960
DEV.ESG/DEV.MSCI	0.96	0.15	0	0.990	EMG.ESG/EMG.MSCI	0.31	0.4	3	0.850
DEV.MSCI/DEV.ENERGY	1.00	0.01	1	0.960	EMG.MSCI/EMG.ENERGY	0.92	0.18	−16	0.350
DEV.MSCI/DEV.FINTECH	0.75	0.12	14	0.330	EMG.MSCI/EMG.GOLD	0.94	0.13	−3	0.860
DEV.MSCI/DEV.ESG	0.04	0.15	7	0.650	EMG.MSCI/EMG.ESG	0.69	0.4	−6	0.730
DEV.MSCI/DEV.FINTECH	0.47	0.48	3	0.870	EMG.MSCI/EMG.FINTECH	0.99	0.02	0	0.980
DEV.ENERGY/DEV.FINTECH	0.00	0.01	86	**0.000**	EMG.ENERGY/EMG.FINTECH	0.49	0.26	25	0.060
DEV.ENERGY/DEV.FINTECH	0.18	0.05	68	**0.000**	EMG.ENERGY/EMG.GOLD	0.56	0.05	30	**0.030**
DEV.ENERGY/DEV.ESG	0.00	0.01	87	**0.000**	EMG.ENERGY/EMG.ESG	0.09	0.2	57	**0.000**
DEV.ENERGY/DEV.MSCI	0.00	0.01	86	**0.000**	EMG.ENERGY/EMG.MSCI	0.08	0.18	59	**0.000**
DEV.GOLD/DEV.FINTECH	0.24	0.11	66	**0.000**	EMG.GOLD/EMG.FINTECH	0.43	0.2	35	**0.010**
DEV.GOLD/DEV.ENERGY	0.82	0.05	9	0.570	EMG.GOLD/EMG.ENERGY	0.44	0.05	45	**0.000**
DEV.GOLD/DEV.ESG	0.24	0.12	67	**0.000**	EMG.GOLD/EMG.ESG	0.07	0.14	70	**0.000**

TABLE 6 (Continued)

DEV-DEV					**EMG-EMG**				
	Mean	**SD**	**HE (%)**	***p* Value**		**Mean**	**SD**	**HE (%)**	***p* Value**
DEV.GOLD/DEV.MSCI	0.25	0.12	65	**0.000**	EMG.GOLD/EMG.MSCI	0.06	0.13	71	**0.000**
DEV-EMG					**EMG-DEV**				
DEV.FINTECH/EMG.FINTECH	1.00	0	0	1.000	EMG.FINTECH/DEV.FINTECH	0.00	0	78	**0.000**
DEV.FINTECH/EMG.ENERGY	0.87	0.09	9	0.550	EMG.FINTECH/DEV.ENERGY	0.81	0.26	15	0.300
DEV.FINTECH/EMG.GOLD	0.85	0.06	11	0.450	EMG.FINTECH/DEV.GOLD	0.39	0.18	59	**0.000**
DEV.FINTECH/EMG.ESG	0.60	0.16	17	0.250	EMG.FINTECH/DEV.ESG	0.00	0.02	79	**0.000**
DEV.FINTECH/EMG.MSCI	0.57	0.16	17	0.230	EMG.FINTECH/DEV.MSCI	0.00	0.01	78	**0.000**
DEV.ESG/EMG.FINTECH	1.00	0.02	0	0.990	EMG.ESG/DEV.FINTECH	0.40	0.16	35	**0.010**
DEV.ESG/EMG.ENERGY	0.87	0.1	11	0.470	EMG.ESG/DEV.ENERGY	0.95	0.09	3	0.870
DEV.ESG/EMG.GOLD	0.84	0.07	12	0.400	EMG.ESG/DEV.GOLD	0.72	0.17	22	0.120
DEV.ESG/EMG.ESG	0.61	0.16	17	0.250	EMG.ESG/DEV.ESG	0.39	0.16	38	**0.000**
DEV.ESG/EMG.MSCI	0.59	0.16	17	0.230	EMG.ESG/DEV.MSCI	0.42	0.16	35	**0.010**
DEV.MSCI/EMG.FINTECH	1.00	0.01	0	0.990	EMG.MSCI/DEV.FINTECH	0.43	0.16	29	**0.030**
DEV.MSCI/EMG.ENERGY	0.86	0.11	11	0.440	EMG.MSCI/DEV.ENERGY	0.96	0.08	0	0.970
DEV.MSCI/EMG.GOLD	0.84	0.07	13	0.380	EMG.MSCI/DEV.GOLD	0.74	0.16	17	0.240
DEV.MSCI/EMG.ESG	0.58	0.16	19	0.190	EMG.MSCI/DEV.ESG	0.41	0.16	33	**0.010**
DEV.MSCI/EMG.MSCI	0.56	0.16	20	0.160	EMG.MSCI/DEV.MSCI	0.44	0.16	30	**0.020**
DEV.ENERGY/EMG.FINTECH	0.19	0.26	45	**0.000**	EMG.ENERGY/DEV.FINTECH	0.13	0.09	72	**0.000**
DEV.ENERGY/EMG.ENERGY	0.27	0.07	61	**0.000**	EMG.ENERGY/DEV.ENERGY	0.73	0.07	16	0.270
DEV.ENERGY/EMG.GOLD	0.32	0.06	51	**0.000**	EMG.ENERGY/DEV.GOLD	0.38	0.02	51	**0.000**

(Continues)

TABLE 6 (Continued)

DEV-EMG					**EMG-DEV**				
DEV.ENERGY/EMG.ESG	0.05	0.09	83	**0.000**	EMG.ENERGY/DEV.ESG	0.13	0.1	75	**0.000**
DEV.ENERGY/EMG.MSCI	0.04	0.08	84	**0.000**	EMG.ENERGY/DEV.MSCI	0.14	0.11	73	**0.000**
DEV.GOLD/EMG.FINTECH	0.61	0.18	24	0.080	EMG.GOLD/DEV.FINTECH	0.15	0.06	79	**0.000**
DEV.GOLD/EMG.ENERGY	0.62	0.02	35	**0.010**	EMG.GOLD/DEV.ENERGY	0.68	0.06	17	0.250
DEV.GOLD/EMG.GOLD	0.79	0.04	6	0.700	EMG.GOLD/DEV.GOLD	0.21	0.04	44	**0.000**
DEV.GOLD/EMG.ESG	0.28	0.17	60	**0.000**	EMG.GOLD/DEV.ESG	0.16	0.07	80	**0.000**
DEV.GOLD/EMG.MSCI	0.26	0.16	61	**0.000**	EMG.GOLD/DEV.MSCI	0.16	0.07	79	**0.000**

Note: W_{ijt} is the weight of variable i in a USD portfolio made of two variables i and j. (HE) is calculated as $1 - (\text{Var}H/\text{Var}U)$ where VarH and VarU are the variance of the hedged and unhedged positions, respectively. W_{ijt} is the weight of j volatility in a portfolio with i.

and Giles (2015), who found that the transmission of returns and the volatility among some developed and emerging markets in Asia are nonhomogeneous.

During the war, the directional pairwise connectedness showed that the connectedness between ESG and MSCI and between ESG and FinTech faded, and renewable energy and gold were connected in developed markets. As for emerging markets, the connectedness between renewable energy and FinTech faded. In the combined context, the war intensified the pairwise connectedness, while those between gold and renewable and between gold and FinTech in developed markets faded.

The growing propagation is mainly related to the theory of absorptive capacity, which explains that knowledge is one of the main drivers of economic growth that can lead to a more qualified national workforce capable of absorbing knowledge and new technologies developed in other countries (Foster-McGregor et al., 2017). The Russia–Ukraine war was coupled with mounting concerns of a sharp global slowdown, surging inflation and debt, and a spike in poverty levels. The economic impact has reverberated through multiple channels, including commodity and financial markets, trade and migration links, and adverse effects on confidence. FinTech technologies can transform managerial and organizational processes and optimize companies' performance. Yet, the effect can be counteracted in times of war and crises. In addition, this phenomenon might encapsulate nonfirm-specific traits and the social and cultural contexts that appear crucial to the country-level process of technological accumulation and knowledge propagation (Cohen & Levinthal, 1990). Thus, the ESG index can greatly affect the directional shock contagion between the studied countries. Firms with higher ESG scores decrease their systematic risk (Pástor & Vorsatz, 2020) following the equilibrium theory pushed by investor demand. The Russian invasion of Ukraine has affected the global economy, and the restriction of Russia's fossil fuel exports had considerable environmental cobenefits by moderating adverse effects on European household incomes, with others largely and negatively affecting the Russian economy. Based on Ferrara et al. (2022), the downside risks for the macroeconomy in the euro area are approximately three times higher than those for the US economy. To conclude, the spillover analysis of such indices in such a critical scenario is necessary to keep pace with the contagion effect and its geographical spread and intensity (Boubaker et al., 2022; Boungou & Yatié, 2022; Chortane & Pandey, 2022; Pandey & Kumar, 2022).

Finally, the time-varying behavior of connectedness helped depict whether an asset was a persistent net transmitter or a net receiver. Some persisted in their role as net transmitters/receivers over the studied period, while other indices played an important role during the war as shock senders/absorbers.

As for the hedging ratios, our findings are in line with prior studies showing that negative hedge ratios exist during crisis periods (Akhtaruzzaman et al., 2021).

We can draw two main conclusions from our results. (1) The Russian war increased the connectedness among these indices, without introducing a wide change across indices among the developed and emerging markets as their roles as transmitters/receivers were maintained. (2) The war has changed the role of the indices as transmitters/receivers in the combined context. (3) The emerging indices were the lead transmitters during the war in the combined context. This is consistent with Ferrara et al. (2022), who found that the downside risks for the macroeconomy perceived by financial markets in the euro area are approximately three times higher than those for the US economy, and with Deng et al. (2022) who concluded that stocks with a high climate transition risk did well in the US and did not exhibit such outperformance in Europe, given its dependency on Russian oil and gas.

Using the DCC-GARCH t-Copula model, we constructed the optimal hedge ratios and the portfolio weights to examine the implications for risk management and portfolio diversification. In developed markets, the most efficient hedge combinations were developed FinTech/developed MSCI, developed FinTech/developed ESG, developed ESG/developed MSCI, developed ESG/developed FinTech, developed MSCI/developed ESG, and emerging MSCI/emerging ESG. Though they are costly, they led to a decrease in volatility by at least 96%. This is in line with El Khoury et al. (2022) and Nakai et al. (2016), who proved that ESG funds outperform conventional ones during crisis periods, and with Apriliyanti and Alon (2017), who stated that the social and cultural contexts appear crucial to the country-level process of technological accumulation and knowledge propagation.

7 | CONCLUSION

In the present paper, we investigated the intensity and direction of spillover effects before and during the Russian war in developed, emerging, and combined regional contexts. The data were collected from Thomson Reuters and ranged from May 8, 2020, to May 11, 2022 (the time of writing this paper). We relied on the following indices: FinTech developed index, FinTech emerging index, renewable energy developed index, renewable energy emerging index, FTSE developed ESG index, and FTSE emerging ESG index, in addition to gold developed index, gold emerging index, MSCI developed index, and MSCI emerging index.

We applied the TVP-VAR methodology to extend the dynamic connectedness of the returns of the five indices, and the DCC-GARCH t-Copula model to estimate the conditional (co) variances and DCCs and construct the optimal hedging and portfolio strategies. The TVP-VAR was employed separately in the following three contexts: developed, emerging, and combined countries and for the prewar period and during the war.

The results indicated heterogenous spillover. In developed countries, FinTech, ESG, and MSCI are net transmitters, whereas gold and renewable energy are net receivers in the prewar period and during the war. In emerging countries, ESG and MSCI are net transmitters, while FinTech, renewable energy, and gold became net receivers in both periods. When we combined the 10 indicators to obtain more global representation, we found that the war has a huge impact on the role played by some assets, mainly in emerging markets. During the war, the developed FinTech, renewable energy, gold, ESG, MSCI, and emerging renewable energy became net receivers, while the emerging FinTech, gold, ESG, and MSCI became net transmitters.

We then constructed the optimal hedge ratios and the portfolio weights to examine the implications for risk management and portfolio diversification. These weight strategies were estimated based on the conditional covariances between assets, using the DCC-GARCH t-Copula model.

We concluded that hedging the volatilities of FinTech in developed markets by taking short positions in ESG and MSCI is relatively high (USD 1.02 and USD 0.98), but effective. Similarly, the volatilities of ESG and MSCI in developed markets can be effectively hedged, reaching 99%. ESG in developed markets provides a good hedging opportunity for FinTech and MSCI in developed markets.

When a portfolio can be used by combining indices between developed and emerging markets, we can see that renewable energy in developed markets can be hedged using FinTech emerging, but is less efficient than FinTech developed, being 45% efficient rather than 86%. However, including MSCI emerging or ESG emerging with renewable energy developed is 84%

and 83% effective, indicating the important role of MSCI and ESG in both countries to hedge renewable energy. Similarly, ESG and MSCI emerging can be included with gold to achieve a hedge effectiveness of 60% and 61%, respectively.

The study has many important implications that highlight the need for broader examinations of the determinants of sustainable investment vehicles and hedging strategies in a time of crisis. It is an important analysis for policymakers, regulators, portfolio managers, hedgers, risk managers, investors, and mutual funds who seek to understand the risks associated with such indices in developed and emerging economies.

The study helps to reveal how the economic impact has reverberated through multiple channels, including commodity and financial markets, trade and migration links, and the adverse impact on confidence exacerbated by the Russia–Ukraine war. Developing and emerging countries are capable of implementing monetary and fiscal stimulus packages to revive economies, stabilize financial markets, and mitigate contagion effects. They should cooperate to understand the direction of propagation and its main causes. The implications of stock price reactions can be compiled to provide an informative review of the future economic impact and global energy transition.

The study encountered some limitations. Data availability was one of the main limitations as we ended up with a different set of data for the developed and the emerging indices. We recommend that future research should include more indices and shed light on the importance to combine innovative technologies, ESG metrics, and financial and commodities assets. Moreover, future research can use our findings to study the integration of regional sectoral indices with sustainable global indices. New artificial intelligence approaches, such as the advent of ChatGPT, is also important to take into account. Such technology might alleviate the burden of complicated models and simulations to choose the best investment strategies and apply hedging ratios that can account for the dynamic environment and potential crisis.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The authors have declared that there was no use of any previously published material.

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ENDNOTES

1 https://www.jpmorgan.com/insights/research/russia-ukraine-crisis-market-impact

2 https://www.ecb.europa.eu/press/pressconf/2022/html/ecb.is220310~1bc8c1b1ca.en.html

3 https://npkcap.com/venture-capital-begins-to-see-the-convergence-of-fintech-and-climate-finance/

4 https://www.jpmorgan.com/insights/research/russia-ukraine-crisis-market-impact

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